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STUDY PLAN

Assessing Tree Mortality from the Spruce Beetle in the White Mountains of Central Arizona

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INTRODUCTION

Recurrent infestations of the spruce beetle, Dendroctonus rufipennis (Kirby), have occurred throughout the Rocky Mountain Region (1, 2, 3). These infestations have established this bark beetle as an important factor damaging Engelmann spruce, Picea engelmannii Parry (4).

The first reported spruce beetle outbreak occurred in the White Mountains of Arizona early in this century (5). Several infestations have occurred in these mountains since then. Between 1948 and 1953, an infestation killed an estimated 22 percent of the Engelmann spruce resource. The next infestation began in 1968 and lasted until 1973. This infestation was evaluated annually and damage surveys were conducted.

The objective of this study is to precisely measure tree mortality in an undisturbed area where the latest spruce beetle infestation caused the greatest tree losses. The maximum effect of the spruce beetle on the tree resource can be determined by taking this approach. Taking measurements in an area, which will remain undisturbed, is a prerequisite for a planned future study on stand development following this infestation. The information on tree losses and stand development will be helpful in assessing spruce beetle impact on timber resource management.

BACKGROUND

INFESTATION AREA

The infestation occurred in the White Mountains of east central Arizona (Fig. 1). These mountains form one of the prominent ranges on the Mogollon Plateau, with elevations reaching 11,430 feet at Mount Baldy Peak. The spruce-fir forest type occupies about 45,000 acres above 9,000 feet. While Engelmann spruce occurs at higher elevations in pure stands, at lower elevations it mixes with blue spruce, Picea pungens Engelm., corkbark fir, Abies lasiocarpa var. arizonica (Merriam) Lemm., Douglas-fir, Pseudotsuga menziesii var. glauca (Beissn.) Franco, and quaking aspen, Populus tremuloides Michx. The forest lies in nine major drainages: Becker, Bonito, Diamond, East Fork, Ord, Paradise, Reservation, Smith, and West Fork. Eight of the drainages, covering about 38,000 acres, are on the Fort Apache Indian Reservation. West Fork drainage, with about 7,000 acres, comprises the Mount Baldy Wilderness of the Apache-Sitgreaves National Forest. The White Mountain Apache Tribal Council also has set aside 7,000 acres of their forest in East Fork drainage as a Primitive Area, subject to periodic review by the Council.

HISTORY OF 1968-1973 INFESTATION

The initial signs of increased spruce beetle activity were found in logging debris examined in Becker and Diamond Creek drainages in 1967 (6). The populations were confined to downed material where an average of 74 larvae per square foot of bark were counted in Becker Creek and 48 per square foot in Diamond Creek. A ground-check in October 1968 revealed that 40 standing green trees had become infested in Becker Creek adjacent to the cutting areas and 60 trees along the boundary between West Fork and Reservation Creek drainages where no cutting was done.

Evaluation surveys to quantify tree losses began in 1969 and continued each year through 1973. All drainages were surveyed at least twice during this period, except the lower portion of East Fork, which was never surveyed. The upper part of East Fork drainage was combined with Bonito drainage. The annual losses and acres surveyed each year for each drainage are shown in Table 1, Appendix.

The first survey was made during the fall of 1969 using $\frac{1}{2}$ chain-wide strips at 10-chain intervals in Becker and Reservation Creek drainages and included counts of infested trees in 1968 as well as 1969 (7, 8). The survey indicated a light infestation in Becker Creek and a sharply increasing infestation in Reservation Creek. A suppression program of salvage logging and green trap trees was recommended for Reservation Creek (8). The salvage logging was completed in 1971.

In 1970, surveys were conducted in all the major drainages (9, 10). One-tenth acre fixed plots were used at 2-chain intervals along lines spaced 10 chains apart. The counts of infested trees showed that the infestation was spread throughout the White Mountains and had intensified since the previous year. An integrated suppression program of salvage logging, green trap trees, and lethal cacodylic acid-treated trees was recommended for 1971 in Becker, Diamond, Ord, Paradise, Smith, and Reservation drainages (9).

During the first week of January 1971, record-cold temperatures of -40° F. killed 88 percent of the spruce beetle larvae above the snow in standing trees in Becker, Ord, Paradise, Reservation, and Smith drainages (11). Larvae and hibernating adults below the snow level experienced only 15 and 28 percent mortality, respectively. These severe winter temperatures reduced the infestation to such an extent that the planned suppression program was canceled. Nevertheless, logging began in Ord, Paradise, and Smith drainages.

The 1971 survey in Diamond, Ord, Paradise, and Smith drainages provided an opportunity to develop stand tables by tree species in terms of living and beetle-killed trees and stand densities per acre (12). Plots were taken at 5-chain intervals along lines 10 chains apart. Trees were sampled on variable-radius plots using a 20 basal-area-factor (BAF). Changes in number of living trees per acre and diameter distributions for spruce, basal areas per acre for host and non-host species, merchantable volumes, and tree species composition were also studied. The spatial pattern of tree mortality was prepared by using ADP print-out overlay maps for each drainage. Bark samples from infested trees were collected for analysis of attack density and brood production. Knight's sequential sampling plan (13) was used to predict the spruce beetle population trend.

The 1972 survey was made in the same drainages as the previous year, but only with half the sampling intensity (14). The variable-radius plot method was used with a 10 BAF. Only standing and wind-thrown trees infested during 1972 were measured. Bark samples from standing infested trees were taken and the population trend determined using Knight's sequential plan.

The 1973 survey was conducted in Becker, Bonito, Ord, Paradise, and Smith drainages along survey coordinate lines established during previous surveys (14). Becker and Bonito drainages were surveyed in the same way as during the 1971 survey and the other three drainages were surveyed just as they had been in 1972. In addition, attacks on standing trees were classed as to whether they were partially or completely infested. No beetle population measurements were taken.

A limited evaluation survey was conducted in part of Bonito Creek drainage during October 1974. The spruce beetle population was found to be at a very low level. Only a few 1974-infested spruce were found and most of these previously had been partially infested.

The greatest amount of tree mortality attributable to the spruce beetle was found in Reservation, West Fork, Bonito, and Paradise drainages (Table 1). Most of the tree mortality occurred during 1969 and 1970. Little additional tree mortality was measured after the severe winter temperatures in 1971. The control effort in Reservation drainage reduced the tree mortality even further in this area.

To characterize tree losses caused by the spruce beetle in an area of heavy spruce mortality, the upper portion of Bonito drainage (Fig. 1 and 2) was examined using 1973 survey data. This area contained a pure stand of Engelmann spruce. The diameter distribution for live, beetle-killed, and total trees in numbers and basal areas per acre was determined (Table 2), and the total statistically analyzed (Table 3). Before the infestation, upper Bonito drainage

contained 233.6 ± 20.8 trees (5.0 inches in diameter and larger) and 218.3 ± 14.2 square feet of spruce basal area per acre. The spruce beetle killed about 38.3 ± 7.2 trees and 61.4 ± 9.4 square feet of basal area per acre. This mortality represents 16 percent of the stems and 28 percent of the basal area per acre. Thus, in an area of heaviest spruce mortality, the spruce beetle killed about one-third of the stand. It is assumed that tree mortality in West Fork drainage was at least equivalent to this because total tree mortality was greater during 1970 and 1971 (Table 1).

METHODS

STUDY AREA

The following criteria have been used to locate the study area in West Fork drainage:

1. Greatest tree losses - the drainages where the latest spruce beetle infestation caused the greatest tree losses. Reservation, West Fork, Bonito, and Paradise drainages meet this criterion.

2. Undisturbed stands - the drainages which have not been logged. Only West Fork and Bonito drainages meet this criterion, since they are in wilderness and primitive areas, respectively.

3. Permanent natural areas - the drainages which will remain undisturbed. Only West Fork drainage has been formally designated as part of the National Wilderness Preservation System under the Wilderness Act of 1964 (P.L. 88-577).

West Fork drainage lies northeast of Mount Baldy (Fig. 1). The mountain is of volcanic origin and has moderately rugged topography, ranging from 9,000 feet elevation to 11,430 feet at Mount Baldy Peak. West Fork is the headwaters of the Little Colorado River. West Fork drainage lies in the Mount Baldy Wilderness which is administered by the Springerville Ranger District of the Apache-Sitgreaves National Forest. The drainage will be reached along the West Fork trail from Sheep Crossing.

The 1970 evaluation survey (10) showed that most of the spruce mortality occurred in upper West Fork drainage between the Little Colorado River and the Wilderness boundary to the south. A $\frac{1}{2}$X1$\frac{1}{2}$-mile (480 acres) rectangular study area will be located there in sections 12, 13, and 14, T6N, R26E, and sections 7 and 18, T6N, R27E (Fig. 4).

DATA COLLECTION

The study area will be systematically surveyed with permanent plots spaced on a 5X5-chain grid. A total of 192 plots will be sampled. This is about the same number of samples taken in upper Bonito drainage, but at about twice the intensity. A more precise estimate of tree mortality should result. Cruise lines spaced 5 chains apart will be run parallel to the long side of the study area. The starting point for the survey will be located in the northern corner of the study area and easily found along the main tributary of the West Fork drainage in section 7, T6N, R27E (Fig. 1).

Two types of plots will be established. A 1/100-acre, fixed-radius plot (11.8 ft. radius) will be used for trees less than 5.0 inches d.b.h. (diameter at breast height - 4.5 ft.). Only the number of trees less than 5.5 feet in height will be counted. Trees greater than 5.0 inches d.b.h. will be sampled on a variable-radius plot using a 20 BAF. A Spiegel-Relaskop will be employed to measure the critical angle from each plot center. Plot centers will be 5 chains apart along cruise lines. Each plot center will be marked with a one square inch redwood stake, 18 inches long, and with a numbered metal tag. Only standing trees will be tallied. Diameter outside bark (d.o.b.) will be recorded for all living trees, and diameter inside bark (d.i.b.) will be recorded for dead trees that do not have the bark in place. D.o.b. can be computed from d.i.b. (16) to reconstruct stand structure and density before the infestation. The d.b.h. of each tree will be measured to the nearest 1-inch class (e.g., 5-inch class = 5.0-5.9; 6-inch class 6.0-6.9, etc.) up to the 44-inch class. Each tree will be recorded by species, and Engelmann spruce will be further classed as either living or killed by the recent spruce beetle infestation. The presence of bark with old beetle galleries and emergence holes and small twigs in the dead crown will be used to separate recently killed trees from snags without bark. Partially attacked trees with green crowns will be considered as live trees. The tree measurement data will be tallied on a form designed for use with the NSEC computer program.

The presence of two important Engelmann spruce diseases, western spruce dwarf mistletoe, Arceuthobium microcarpum (Engelm.) Hawksworth and Wiens, and spruce broom rust, Chrysomyxa arctostaphyli Diet., will be determined in the study area. Because both pathogens cause tree growth loss and mortality, knowledge of their occurrence is considered essential for planning a future study on stand development after the spruce beetle infestation. The incidence of western spruce dwarf mistletoe in portions of the White Mountains was evaluated recently (17) and found to be rare above 10,000 feet. No comparable information is available for spruce broom rust. The presence of

dwarf mistletoe will be noted if the aerial shoots or associated witches' brooms are visible on the plot. The brooms are small and dense (18) and easily distinguished from those formed by the broom rust, which are large and yellowish during the summer (19).

The presence of Engelmann spruce pathogens will be recorded on the form shown in Figure 5.

DATA ANALYSIS

The field data will be analyzed by the NSEC computer program. Prior to using this program, the d.i.b. of beetle-killed trees will have to be converted d.o.b. using the equation from (16): d.o.b. = 1.0508 (d.i.b.) + 0.2824.

The incidence of dwarf mistletoe and broom rust will be determined as a percent of the plots on which each pathogen was found.

DUTIES AND RESPONSIBILITIES OF FIELD PERSONNEL

The field survey crew, consisting of four members, will be responsible to a survey coordinator who in turn will report to a supervisory entomologist.

The supervisory entomologist's duties will be to:

1. Plan the survey.

2. Coordinate with forest and district staff.

3. Brief crew members on purpose of survey.

4. Provide training on survey procedures, tree measurement techniques, and safety.

5. Check survey quality.

The survey coordinator's duties will be to:

1. Assemble equipment and supplies for the vehicles, survey, and camp.

2. Issue survey equipment to crew.

3. Locate pre-survey field reference points.

4. Assist with training.

5. Coordinate survey crews.

6. Periodically check the accuracy of the survey in addition to the supervisory entomologist.

7. Collect and compile survey data.

8. Keep supervisor informed of survey progress.

Each field crew member's duties will be to:

1. Properly maintain vehicles, camp equipment, and survey equipment.

2. Correctly and unbiasly apply demonstrated survey procedures and tree measurement techniques.

3. Wear approved personal protective equipment.

4. Work in a safe manner.

SAFETY

Each crew member has the following responsibilities to himself and his fellow workers:

1. Surveying

   a. Wear appropriate field clothing.

   b. Use personal protective equipment, such as boots, gloves, and hard hats.

   c. Properly use survey equipment and methods.

   d. Exercise care when walking and working, paying special attention to footing on logs and other debris.

2. Camping

   a. Locate and establish in a safe place.

   b. Locate near safe drinking water.

   c. Completely extinguish fires at night and when leaving camp.

   d. Delegated tasks and chores are to be shared by all crew members.

e. Maintain tools and camp equipment in good condition.

f. Possession of firearms is not permitted in camp.

g. Keep camp clean and orderly.

3. Vehicles

a. Only qualified personnel who a government driver's license will operate the vehicles.

b. Drive at a safe speed and manner for existing road conditions.

c. Insure that vehicles are maintained in good repair and service as scheduled.

d. Make sure tools required for handling breakdowns and flat tires and forms for accidents are in vehicles.

e. Turn in mileage sheets and gasoline and maintenance receipts to FIDM clerk on 20th of each month.

EQUIPMENT AND SUPPLIES

Each crew member will be issued personal protective equipment (a hard hat) and survey equipment (map, compass, hatchet, etc.) by the survey coordinator. All equipment will be issued on an individual basis and each member will be held personally responsible for repairing or replacing equipment lost or damaged through neglect or misuse.

1. Survey equipment	Quantity
Day pack	2
First aid kit	2
Hard hat	4
Hatchet w/sheath	4
Compass	4
Map, 15-minute topographic	4
Diameter tape	4
Relaskop	3
Logger's tape, 75-foot rewind	3
Field data sheets	250
Flagging, roll, candy stripe	1 dozen
Redwood stakes, 1X1-inch	200
Metal tags, numbered	200
Pens	1 dozen
Tatum	2
Canteen	4
Limiting distance table, 20 BAF	4
Binocular, 7X35	2

2. Camp equipment	Quantity
Tent, 8-man, wall	1
Tent poles (pipe frame)	1 set
Fly	1
Cot, folding	4
Lantern, Coleman	2
Stove, Coleman	2
Heater	1
Coleman fuel	4 cans
Fuel funnel	2
Ice chest, Coleman	2
Cooking pots and pans	1 complete mess set
Eating and cooking utensils	1 complete mess set
Tarpaulin, tent floor	2
Pulaski w/sheath	1
Shovel	1
Hand saw	2
Ax	2
Water container	2
Rope	200 feet
Paper towels	5 rolls
Toilet paper	5 rolls
Broom	1
First aid kit	2
Accident forms	4

3. Vehicle	Quantity
Tool box, to include hammer (sledge), screw drivers (Phillips and standard), pipe wrench (2), pliers, crescent wrench set, wire brush, files (2 flat, 1 round), insulation tape	1 complete
Peavey	1
Shovel	1
Pulaski w/sheath	1
Ax	1
Tire chain	1
Tow chain	1
Hydraulic bumper jack	1
Winch	1
Fire extinguisher	1
First aid kit	1

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A P P E N D I X

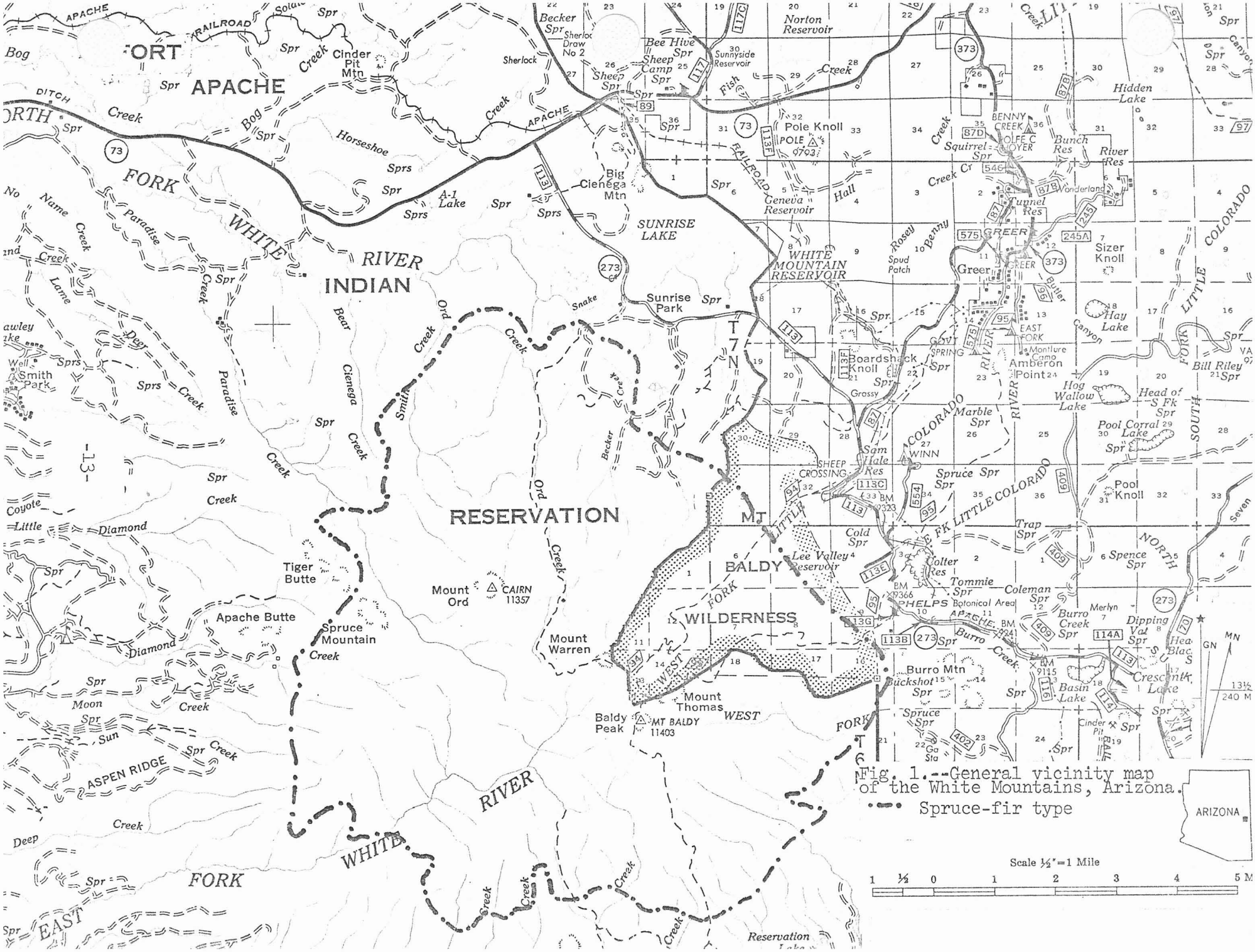


Fig. 1.--General vicinity map of the White Mountains, Arizona.
Spruce-fir type

Fig. 2.--Oblique aerial view of upper Bonito Creek drainage, White Mountains, Arizona, 1973.

Fig. 3.--Engelmann spruce forest in upper Bonito Creek drainage where spruce beetle killed 16 percent of the trees and 28 percent of the basal area.

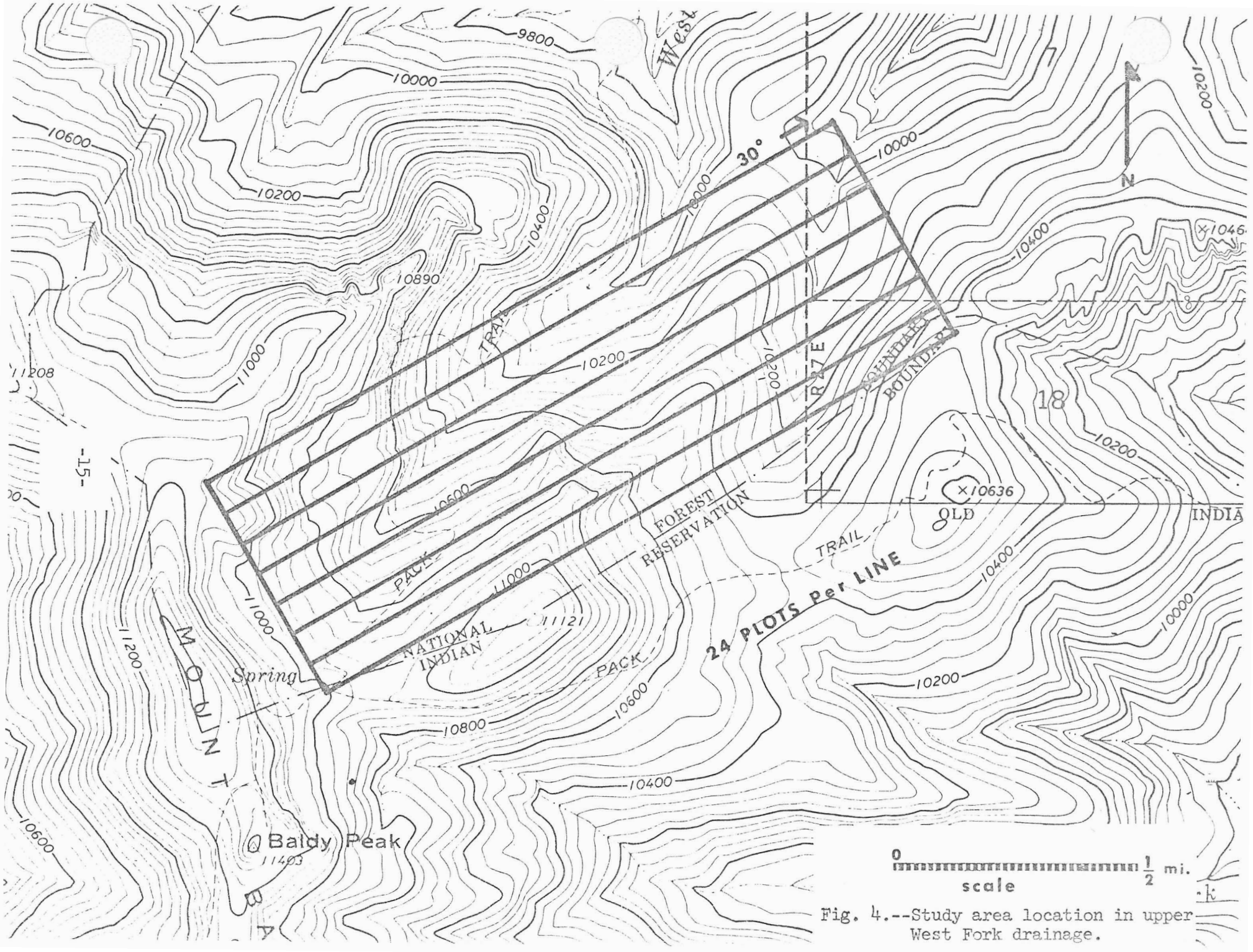
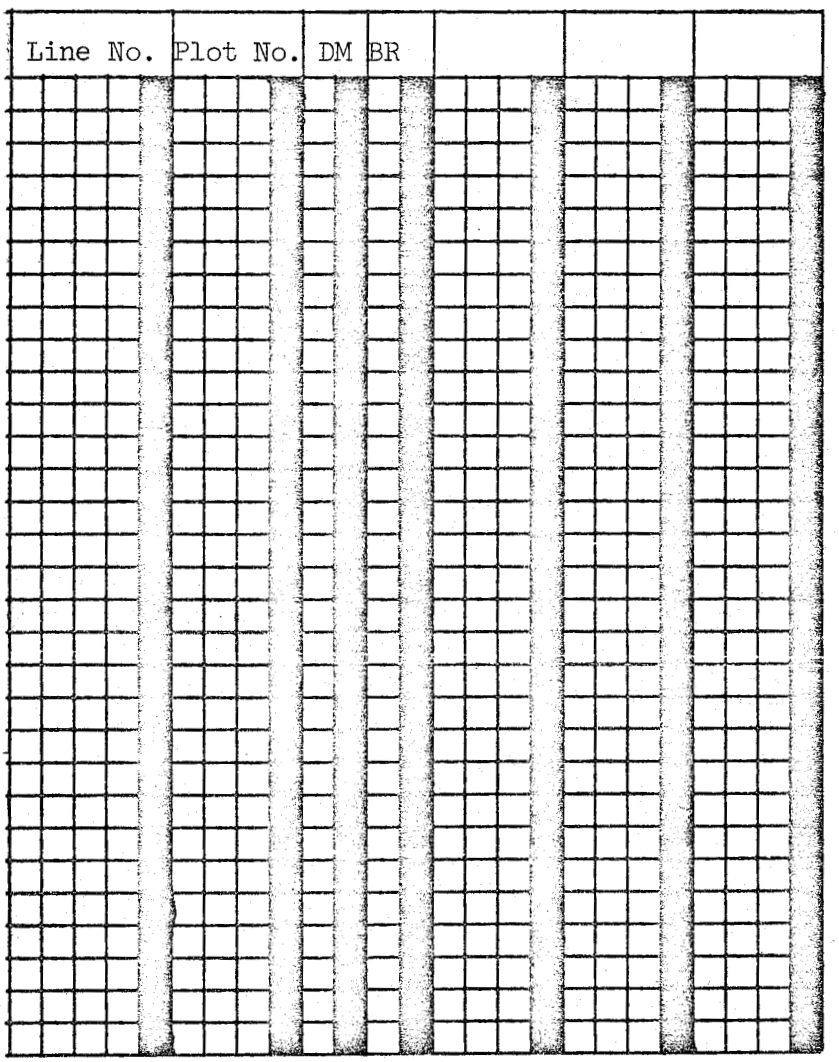


Fig. 4.--Study area location in upper West Fork drainage.

INCIDENCE OF ENGELMANN SPRUCE PATHOGENS



Date: _____ Crew: _____

Location: _____

"+" signifies presence

Fig. 5.--Tally form for spruce diseases.

Table 1.--Estimates of annual spruce mortality from spruce beetle infestation, 1968-1973, White Mountains, Arizona.

Drainage	Year of infestation						Cumulative total I/T/A
	1968[10,11]	1969[12,13]	1970[12,13]	1971[15]	1972[16]	1973[17]	
Becker							
I/T/A	.8	1.83	4.79			.45	7.84
A/S	1,716	4,663	4,663			2,700	
Bonito							
I/T/A		4.25	8.2			2.08	14.53
A/S		6,636	6,636			3,740	
Diamond							
I/T/A		3.80	1.14	.7	.06		5.64
A/S		3,565	3,565	2,985	2,985		
Ord							
I/T/A		.91	5.87	1.98	.7	.53	9.29
A/S		4,709	4,709	4,685	4,685	4,770	
Paradise							
I/T/A		4.15	5.37	4.16	.61	.22	13.90
A/S		5,754	5,754	4,540	4,540	4,340	
Reservation							
I/T/A	1.24	3.96	15.20	.24			20.64
A/S	4,556	5,637	5,637	695			
Smith							
I/T/A		1.74	4.52	1.77	.45	.03	8.06
A/S		2,798	2,798	2,755	2,755	2,810	
West Fork							
I/T/A		3.42	15.55				18.97
A/S		2,746	2,746				
Avg. I/T/A	1.12	3.15	7.68	2.25	.50	.68	
Total A/S	6,272	36,508	36,508	15,660	14,965	18,360	

Abbreviations: I/T/A = Infested trees per acre
A/S = Acres surveyed

Table 2.--Stand table for Engelmann spruce within upper Bonito Creek drainage - 813 acres.

D.b.h. (2-inch classes)	Average number of trees per acre					
	Live		Beetle-killed		Total stand	
	Number	Basal area[1]/	Number	Basal area[1]/	Number	Basal area[1]/
6	29.0	5.7	.6	.1	29.6	5.8
8	32.3	11.3	2.5	.9	34.8	12.2
10	36.2	19.7	2.8	1.5	39.0	21.2
12	36.4	28.6	4.0	3.2	40.4	31.8
14	26.2	28.0	8.3	8.9	34.4	36.9
16	16.2	22.6	4.7	6.6	20.9	29.2
18	10.3	18.2	4.7	8.3	15.0	26.5
20	4.9	10.7	3.4	7.3	8.3	18.0
22	2.2	5.9	2.7	7.2	4.9	13.1
24	1.0	3.3	1.9	6.1	2.9	9.4
26	.5	2.0	1.2	4.3	1.7	6.3
28	.1	.6	.8	3.3	.9	3.9
30	.02	.1	.4	1.8	.4	1.9
32	.02	.1	.2	1.1	.2	1.2
34	0	0	.1	.5	.1	.5
36	0	0	0	0	0	0
38	0	0	.03	.2	.03	.2
40	.01	.1	.01	.1	.02	.2
42	0	0	0	0	0	0
44	0	0	0	0	0	0
Total	195.3	156.9	38.3	61.4	233.6	218.3
Percent	83.6	71.9	16.4	28.1		

1/ Square feet.

Table 3.--Statistical analysis for Engelmann spruce in upper Bonito Creek drainage - 813 acres.

Statistics	Engelmann spruce trees		
	Live	Beetle-killed	Total
Sample size	158	158	158
Average/acre	195.3	38.3	233.6
Standard deviation	127.4	45.0	131.2
Standard error	10.1	3.6	10.4
Coeff. variation	65.2%	117.5%	56.2%
Statistics	Engelmann spruce basal area[1/]		
	Live	Beetle-killed	Total
Sample size	158	158	158
Average/acre	156.9	61.4	218.3
Standard deviation	84.5	59.7	88.8
Standard error	6.7	4.7	7.1
Coeff. variation	53.9%	97.2%	40.7%

1/ Square feet.